

Coal, Combustion and the Grand Carbon Cycle

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Summary

Carbon is the most valuable and amazing element on our living planet.

It is the building block of all life on earth, and has provided the food, clothing and most of the energy for every human for all of our history.

Yet carbon is being subjected to an unprecedented campaign of demonization focussed on man's production of carbon dioxide. The main aim of this campaign is to cripple or eliminate the coal industry because combustion of coal produces carbon dioxide.

Carbon dioxide the key link in the cycle of life on earth.

Most people understand the biological carbon cycle - plants using solar energy extract carbon dioxide from the atmosphere, converting it to sugars and proteins, and returning oxygen to the atmosphere. Plant material, directly or indirectly, provides food for all animals. In the process of digesting carbon food, animals extract oxygen from the atmosphere to digest their carbon foods, producing carbon dioxide which is then returned to the atmosphere. More carbon dioxide means more plant growth. This is a sustainable self regulating process.

But there is an even bigger, Grand Carbon Cycle, also involving carbon dioxide.

Carbon dioxide is added to the atmosphere by volcanoes, natural and man-made combustion of carbon fuels such as wood, coal and oil, and out-gassing from oceans during warm climatic eras. This carbon dioxide is removed from the atmosphere by biological and chemical extractions into the oceans to form corals, shell fish and massive deposits of limestone, dolomite and magnesite on the ocean floor. In some eras, large quantities of plant material are also locked away in enormous deposits of lignite and coal. During cool climate eras, oceans also take up huge quantities of carbon dioxide into solution.

Vulcanism and combustion are helpful processes returning valuable carbon dioxide to the atmosphere. Without them, earth's precious carbon supplies would slowly become interred and locked away in massive buried deposits of carbon bearing materials such as limestone and coal.

The products of combustion of all carbon fuels are normal and natural components of the atmosphere, and essential nutrients for all life.

This paper looks at the compositions of solid carbon fuels, the process of coal combustion, the exhaust products produced, and the benefits and pollution potential of those exhaust products.

The Origin and Composition of Coal

Coal is a complex natural product derived from plant material – largely vegetation from ancient forests. This material has been buried, compressed and concentrated into a valuable product with high energy content. It is fossilised sunshine as “green” as any tree today.

Coal contains many hydrocarbons plus variable quantities of various natural minerals. It is often found in seams separated by or mixed with bands of sand, silt and clay. Sometimes this sedimentary material is separated from coal in the mining and processing stages, but sometimes very fine sediments are intimately mixed with the buried plant material and add to the ash residue when the coal is burnt.

Because coal is a natural product derived from many different plants growing in varying soil and climatic environments, every coal seam is different and each seam may vary from place to place.

Coals and other natural solid carbon products are generally classified according to their contents of carbon and volatile matter (things like oils and gases that can be driven off with heat).

Almost every human need is provided by carbon or needs carbon in its production process. Carbon provides all of our food and clothing, most of our energy and building materials and is the building block for every organ in our body. To demonise carbon is to hate ourselves and life itself.

Demonising Carbon

Carbon is the most amazing element on earth. To demonize and make war on carbon is to demonize and make war on life itself. Since our very brains are not only made of carbon, but fuelled by carbon, it is strange that thinking, conscious carbon should now turn around to make war on itself.

Bob Brinsmead

See also:

<http://carbon-sense.com/2010/05/31/green-shoes-and-carbon/>

The table below lists typical properties of the main solid carbon products occurring in nature. There is an even longer list of natural liquid and gaseous carbon products as well as the myriad of life forms on earth. It is time we started telling our children and our politicians the exciting story entitled:

“The Magic World of Carbon”.

Typical members of the Natural Solid Carbon Fuel Family

Carbon Product	Carbon Content <i>Ultimate Composition</i>	Volatile Content	Energy Content <i>Heat avail from complete combustion.</i>
	<i>% by weight</i>	<i>% by weight</i>	<i>MJ/kg</i>
Biomass (grass etc)	46%	74%	18.0
Wood	50%	84%	20.0
Peat	58%	69%	16.0
Lignite	70%	53%	21.5
Brown Coal	77%	42%	26.0
Black Coal	86%	26%	33.5
Semi-anthracite	90%	19%	35.0
Anthracite	94%	4%	34.5
Graphite	100%	0%	32.8
Diamond	100%	0%	32.8

Note: All values are after the removal of moisture and mineral matter.

Sources:

Biomass & Wood: <http://www.woodgas.com/proximat.htm>

Other from "Coal Specifications – Impact on Power Station Performance". IEA Coal Research (IEACR/52), January 1993.

Note: Diamond is pure carbon, and has an energy value, but few people have managed or wanted to set one on fire!! Diamond has no volatiles and the carbon atoms are so locked together that diamond is the hardest natural substance on earth. Graphite, the other pure carbon product, has a totally different atomic structure and is one of the earth's softest minerals, used in "lead" pencils.

The Combustion Process

Combustion is the process whereby carbon fuels are ignited in air so that the carbon combines with oxygen forming carbon dioxide and releasing energy in the process. Most carbon fuels contain hydrogen which produces pure water vapour when burnt.

Combustion can occur in open fires or in confined spaces such as the cylinders of internal combustion engines or in volcanoes. Slow combustion occurs where the oxygen supply is limited as in the old slow combustion stoves or in all animal gut/lung systems.

The exhaust gases from any process which burns carbon fuels in atmospheric air are nitrogen, water vapour, carbon dioxide, argon and other minor and trace gases.

Inefficient combustion occurs when there is too little oxygen for complete combustion of the carbon in the burner. This can result in the formation of carbon monoxide, a deadly gas even in modest concentrations. It is a silent invisible killer. This danger is most acute when gas heaters or combustion stoves burn in closed or poorly ventilated rooms. (Government class rooms being equipped with flue-less gas heaters instead of clean electric heaters are another "green" scandal yet to break).

The Grand Carbon Combustion Cycle

Combustion is a natural and essential part of the earth's grand carbon cycle. Every bit of carbon extracted from the atmosphere by plants using solar energy was put into the atmosphere by some process of combustion.

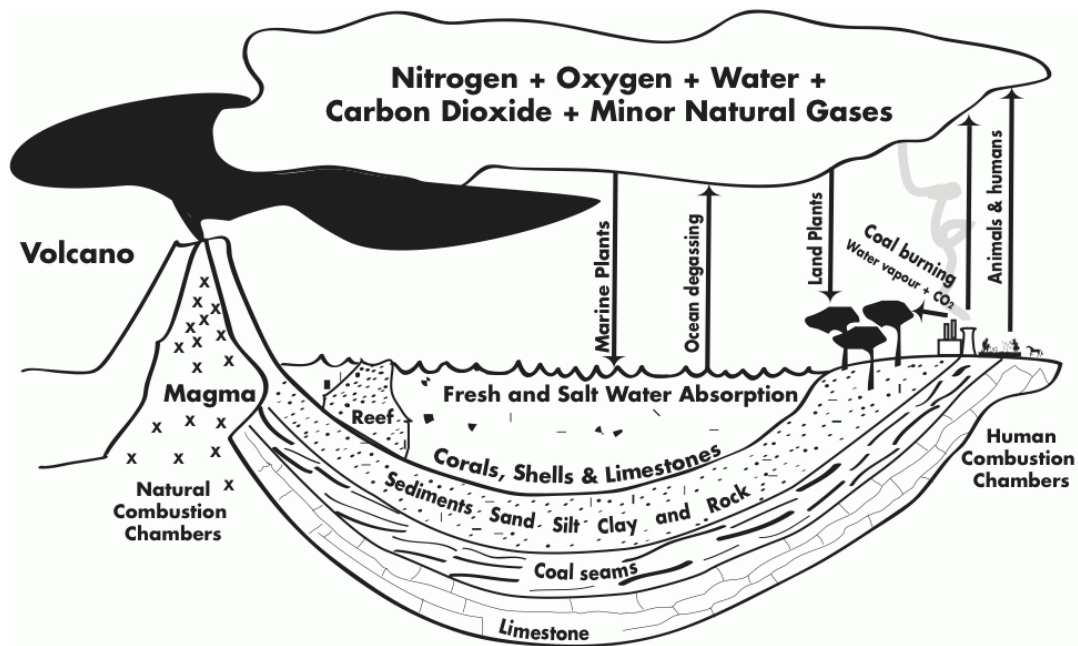
Carbon combustion processes include:

- Bushfires which burn biomass (a pretentious name for grass, trees, leaves and other bushy material). Bushfires are ignited by lightning, falling power lines, sparks from passing machinery, cigarette butts or spontaneous combustion of hay stacks or coal stockpiles. Others are deliberately lit by landowners, firebugs or vandals. The Australian landscape of grasslands and open forest evolved under a regime of regular natural and aboriginal bushfires.
- Cooking fires using wood, coke, dung, coal, oil or gas.
- Animals digesting food (which is also a carbon fuel) in a slow combustion chamber deep within the gut and lungs. The gaseous products of this combustion (mainly carbon dioxide and water vapour, with some methane and smelly gases) are also returned to the atmosphere from whence they came.
- Billions of termites, other insects, bacteria and soil microbes.
- Reactions which occur as a result of volcanic eruptions, earth movements and impacts from comets and asteroids. Impacts from comets are rare events but vulcanism, on land and beneath the oceans, is occurring all the time. Rising molten magmas can intrude sediments, coal seams and moist rocks. The extreme heat alters the intruded rocks, calcining limestone and driving volatiles from any hydro-carbon bearing strata. Once oxygen is present, these volatiles burn like any other carbon fuel. The gaseous products of heating and combustion are exhausted to the surface, sometimes explosively, in huge clouds of gases and ash.
- Steam engines using heat generated from burning natural carbon fuels such as wood, gas, oil or coal.
- Internal combustion engines burning natural gas or petroleum products.

Every one of these combustion processes produces carbon dioxide and water and returns them to the atmosphere. This carbon dioxide was previously extracted from the atmosphere by plants. Without this process of recycling by combustion, the carbon dioxide plant food reserves of the atmosphere would become depleted and plants would begin to starve. Soon after this, animals would begin to starve. Plant growth would cease once carbon dioxide levels in the atmosphere were reduced to about half of current levels.

Billions of tonnes of the earth's valuable carbon are locked away by earth processes in massive deposits of limestone, dolomite, magnesite, lignite and coals. Volcanoes, coal miners and cement plants return a tiny fraction of these sterile carbon resources to the biosphere.

The Grand Carbon Combustion Cycle



Natural surface phenomena such as volcanoes, earth quakes, tsunamis, lightning, cyclones and hurricanes put enormous amounts of gases, chemicals and dusty mineral matter into the atmosphere. The earth has an enormous capacity to recover from these disturbances without reaching any tipping points.



Nature dominates the atmosphere.

Major Exhaust and Ash Products from Coal Burning

For an explanation of the tonnages of exhaust products produced from burning typical black coal see:

<http://carbon-sense.com/2010/05/14/coal-burning/>

The major exhaust and ash products resulting from combustion of a typical black coal in air are:

Exhaust Product	% of Total	Cumulative % of Total
Nitrogen	69%	69%
Carbon Dioxide	21%	90%
Water Vapour *	7%	97%
Argon etc	1%	98%
Ash (residual mineral matter)	2%	100%

**This figure excludes water used in the steam turbines, much of which is cooled and condensed in the cooling towers and reused. The water lost in this process, pure distilled water, drifts back into the atmosphere from the cooling towers.*

This table shows that most of the exhaust products from modern coal power stations are composed of the harmless natural gases – nitrogen, carbon dioxide, water vapour and argon. These gas emissions together comprise 98% of the exhaust products generated by burning coal.

Every one of these gaseous products either came from the atmosphere and was unchanged in the burners (nitrogen and argon), or is a natural atmospheric product created by burning any carbon fuel in oxygen (carbon dioxide and water).

“Ash” is a solid inert residual formed from plant derived mineral matter and mineral sediments contained in the coal seams.

Minor Exhaust Gases from Coal Burning

Two minor natural components in the coal combustion process sometimes produce problems in exhaust gases – sulphur and nitrogen.

When coal is burnt, these elements are transformed to gaseous oxides of sulphur (often referred to as SO_x) and oxides of nitrogen (often referred to as NO_x).

(Incidentally, some forest timbers also have a very high sulphur content and will also produce SO_x when burnt. Some weeds also have a high copper content.)

In remote rural areas, trace amounts of these and other plant nutrients are very beneficial when dispersed by winds, dissolved in clouds and recycled to our leached soils in rain. Keen gardeners and pastoralists who treat their lawns, gardens and pastures with ammonium sulphate (NH_3SO_4) will recognise the benefits of such cost-free aerial fertilisation.

However, both SO_x and NO_x have a pungent irritating smell, can result in acidic rain and are unacceptable when concentrated in closely settled areas. Thus community pressure has forced coal burners in developed countries to remove most of these compounds from emissions to avoid air pollution.

NO_x is controlled by selection of low nitrogen coals and/or by good coal burner design. SO_x is controlled by selecting low sulphur coals and by removal of SO_x after combustion.

Markets are increasingly demanding coals that are low in nitrogen and sulphur and such coals attract a higher price. Other coals face price penalties to compensate for the costs of extra pollution control.

Control of SO_x (oxides of sulphur) in Boiler Exhaust Gas

Coals contain variable quantities of sulphur bound up in the coal or in associated minerals. When the coal is burnt, sulphur tends to be liberated as a gas, mainly sulphur dioxide.

This gas dissolves readily in water and is washed from the atmosphere by rain. In trace amounts it is generally beneficial to plant life, but in high concentrations close to power stations it can form damaging "acid rain". It is especially detrimental in urban areas where high sulphur coal or oil is burnt locally.

Tall flue gas chimneys will disperse the emissions by diluting the pollutants well above ground level and distributing them harmlessly over large areas.

Stringent environmental protection regulations regarding SO_x emissions have been enacted in most western countries. Technology has provided the solutions.

Flue gas desulfurization (FGD) is a technology used for removing SO_x from the exhaust flue gases of coal or oil fuelled power plants. There are a variety of methods, with the following being the most common:

- Wet scrubbing using a slurry of alkaline absorbent, usually limestone or lime, or seawater to scrub the gases. This can produce gypsum, a valuable by-product.
- Spray-dry scrubbing using similar absorbent slurries.

- Wet sulphuric acid process recovering sulphur in the form of commercial quality sulphuric acid.
- SNOX Flue gas desulphurisation, another process that removes sulphur dioxide, nitrogen oxides and particulates from flue gases.
- Dry absorbent injection systems.

For a typical modern coal-fired power station, flue gas desulphurisation will remove 95% or more of the small amounts of SO_x in the flue gases.

Control of NO_x (oxides of nitrogen) in Boiler Exhaust Gas

Coal burners, especially those where the design is not appropriate for the coal they are burning, can convert some of the harmless nitrogen in the coal to oxides of nitrogen (NO_x). Lightning creates the same gases in the atmosphere. Generally these gases are also very beneficial plant fertilisers when they are washed into the soils by rain. But like almost all gases, they can be suffocating or even poisonous in high concentrations.

There are two main ways of keeping NO_x low in the exhaust gases:

1. Choose coals of low nitrogen content. Coals with lower nitrogen are often preferred with a limit in many places of 1.8% (dry ash free basis). Power stations burning low nitrogen coals may then not need to fit low NO_x burners. Some places have very stringent environmental controls that make low nitrogen coals mandatory. (Combustion does not seem to affect the huge quantities of nitrogen in the air taken into the burners.)
2. Burn the coal in specially designed coal burners that keep the flame temperature down. The higher the flame temperature the greater the problem. Air is added in stages to accomplish this.

Solid Residue from Coal Burning

All plant material including coal contains mineral components that remain in the ash residue after combustion. The major tonnage of solid residue produced by burning coal comes from ash, soot and unburnt carbon.

What happens to the ash?

In a pot bellied stove, some ash is drawn up the chimney with the draft and drifts down onto the roof or onto nearby lawns and gardens. However most of the ash accumulates in the bottom of the stove and has to be emptied regularly. It is great top dressing for gardens, can be used to make soap, chooks love to fluff their feathers in it to remove ticks and lice, and other animals like to roll in it.

Even in a roaring open fire some carbon remains unburnt when the flame is chilled. As anyone who has lived near sugar cane fires knows, soot goes up with the smoke and comes down onto the clothes on the washing line.

Modern power station coal burners are designed to ensure that sufficient oxygen is supplied to ensure that all carbon is burnt and no soot or carbon monoxide goes up the chimney. The ash is either removed from the hearth of the furnace as slag or, if carried aloft with the burnt gas, caught in filters and precipitators.

The quantity and composition of solid waste produced depends on the composition and processing of the original coal.

“Ash” in the original coal is expressed as a percentage by weight of the feed coal. Some rare coals from Indonesia and New Zealand have very low ash content (less than 5%) but most traded thermal coals have ash levels in the 10% - 15% range. Some inland power stations in China and India burn some very high ash local coals (greater than 20% ash) because of the high cost of transport for better quality imported coal.

There is no upper limit to the ash content but once ash exceeds say 50% the material would be called, not coal, but carbonaceous shale or black shale. It has a low energy content and is seldom used for energy generation.

It is generally uneconomical to transport high ash thermal coals over long distances. Australian thermal coals of export quality have to be transported over long distances to markets in places like Europe, Asia and South America. Thus low ash coals are selected. Most of them are also washed before leaving the mine to reduce ash and impurities, to optimise energy yield and to reduce transportation costs. Australian export quality coals are therefore among the cleanest in the world coal trade.

In a typical traded thermal coal, with ash of about 13%, boiler ash would comprise about 2% of the total tonnage of waste products from the power station.

In some places these solid residuals are used to make beautiful ceramic building bricks. Fly ash is added to cement to make concrete and can also be used as a soil conditioner. Slag (fused ash) can be used as road base.

Carbon Dioxide and Plant Growth.

Nurserymen know well that carbon dioxide encourages plant growth. They burn natural gas in their nurseries. This does three things that encourage plant growth – increases the warmth, increases the humidity and increases the availability of aerial plant food, carbon dioxide. Asian orchardists also light small fires beneath their fruit trees to provide extra carbon dioxide nutrition.

Looking at the long history of the earth, current levels of carbon dioxide in the atmosphere are low, well below the levels that prevailed when many plant and animal species evolved. As a result, some plants are already suffering from some degree of carbon starvation. Even at today's levels of carbon dioxide, analyses done in the middle of the day above a virile crop of corn will show that air is almost devoid of carbon dioxide - the growing corn has extracted it all. Plant life would be far stronger if carbon dioxide levels were double or treble current levels (as it was when many rich coal seams were formed).

See: <http://carbon-sense.com/2010/04/15/carbon-dioxide-time-lapse/>

Carbon dioxide is heavier than air. Normally, because it is warm when it exhausts from a combustion chamber, it rises in the cooler atmosphere, and wind soon disperses it fully throughout the atmosphere. But in gentle breezes or very cold air it could tend to drift downwind staying closer to the ground, thus feeding plants along that path.

This beneficial effect on plant growth around coal fired power stations has been noticed by at least two observers.

One concerned the Great Lakes area of USA. At a lecture given in 2006 Dick Underwood, a retired NASA scientist showed a satellite view showing steam emerging from condenser towers at a power station complex on the east side of the Great Lakes district.

He commented that farm land down-wind of the power stations proved more productive than elsewhere in the district and was therefore a sought after location.

Another concerned trees around the Tarong Power Station in Queensland. Forestry research into methods of tree pruning led to the observation that trees in the vicinity of the Tarong Power Station are growing more vigorously than similar trees 15 km away (over 200% more timber growth in 10 years). See: <http://carbon-sense.com/2010/06/03/tree-growth-near-power-stations/>

This suggests that the plant food from coal fired power stations should be looked on as an asset, not a liability. Power stations also emit large quantities of steam (pure water vapour) which is also a benefit for Australia's often thirsty landscape.

Another study of 70,000 trees across 10 African countries and compared them with similar records made four decades ago. On average, the trees were growing faster (as carbon dioxide levels rose).

See also: http://www.naturalnews.com/027779_carbon_dioxide_forests.html

Coal, Nutrients, Trace Elements and Health

There is NOTHING in coal that is inherently harmful to plant or animal life for the simple reason that almost everything in coal came from living plants (minor amounts of mineral matter might have been added later by circulating groundwaters).

To survive, all plants need water, carbon dioxide, nitrogen and solar energy. All animals rely on plants to produce their food. All plants and animals also need many trace minerals such as calcium, magnesium, sodium, potassium, phosphorus, sulphur, copper, chlorine and selenium, most of which occur in coal with the right balance and in trace amounts.

In remote areas, most of the chemicals produced by burning any natural carbon product such as biomass, wood or coal are very beneficial to soils and plants. Many Australian soils are very deficient in sulphur and nitrogen, so animals are healthier if supplemented with lick blocks containing sulphur and protein supplements (which contain nitrogen).

Volcanoes can release huge quantities of sulphur, so volcanic areas are not deficient in this nutrient. Hot springs and even artesian bores release sulphur into the atmosphere. Even some shallow non-artesian bores, as well as coal seam gas operations can release sulphurous gases, so there is much in the air that does not come from coal combustion. Much of Australia, however, has been stable for eons, and many soil minerals have been leached out by rain or extracted by crops and pasture and consumed by generations of human and animal harvesters.

Here are a couple of products often supplied as dietary supplements to domestic sheep and cattle. They can choose to eat them if they wish and most of them do eat them when they feel they need them:



These blocks and other supplements supplied to grazing animals contain the following elements:

- Calcium, Magnesium, Sodium, Potassium, Sulphur, Chlorine, Phosphorus, Iodine, Selenium, Copper, Cobalt, Carbon, Nitrogen, Bentonite (clay)

Every one of these plant and animal nutrients is found in coal and coal measures. Where a coal seam outcrops (intersects the surface), the processes of surface weathering will release these valuable components to produce beautiful, dark, fertile, humus-rich soil covered in healthy grass and trees. Coal is not “dirty” – it is as green as the plants it came from and as healthy as the best fertile soil.

The trace elements in coal largely reflect the nutrients which were needed by the plants which formed the coal. The nutrient quantities are thus balanced to meet the needs of the plant.

Balance is the key to most things in life. A balanced diet includes enough iodine/copper/selenium etc but not too much. A balance is also needed between, for example, calcium and magnesium, or copper and cobalt. The beauty of coal is that the plants from which it was formed have already selected every element needed by growing plants in exactly the right ratios. The balance of mineral nutrients is just right.

Naturally the ingredients in coal ash are concentrated by the burning process, and have had all their volatile organic constituents driven off. So while coal ash can be used as a mineral fertiliser, it is not soil, and must be enriched with other constituents like humus and soil microbes before it can become fertile soil again.

Plant Foods or Pollution?

ANYTHING can be harmful if it is too concentrated. We will drown in 100% water, suffocate in 100% carbon dioxide and suffer breathing problems in 100% oxygen. We need magnesium for adequate health, but too much will cause diarrhoea. Deficiency of copper will cause snowy white hair and aneurisms, but too much copper will poison you.

I can say from the experience of once living downwind from the old copper smelter in Mount Isa that too much sulphur dioxide is not pleasant and can kill pumpkin plants in the vegie garden on a dewy morning. But if sheep graze on soils or feed that is deficient in copper and sulphur, they tend to get worms, lice and other parasites.

Boilers and furnaces have tall chimneys whose purpose is to spread the trace elements over a large area, because the designers know that, in many situations:

“The solution to pollution is dilution.”

The pollution problem is not coal or industry – pollution problems generally occur in places with high population density, low incomes and primitive technology. In such situations the environment is overloaded and humans can be gradually poisoned even with normally harmless natural products. Thus remote coal fired power stations producing clean electricity create no pollution problems whereas a million dung stoves, wood heaters or primitive coal boilers in urban environments can create unhealthy concentrations of noxious gasses or even deadly smog.

For a discussion on Asian Brown Smog see:
<http://carbon-sense.com/2008/08/04/clearing-the-smog/>

Keeping a Sense of Perspective on Emissions

One volcano can spew out more NO_x, SO_x, chlorine and carbon dioxide in a few days than many large and dirty power stations could emit in a lifetime. Nature has no electrostatic precipitators, filters or bag houses removing ash and no gas pollution control equipment except dilution by winds and wash out by rain.



Gas Emissions - Iceland Volcano on left, Bayswater Power Station on right.

**You can see the wispy white steam emerging from the power station cooling towers.
But can you see the “pollution” (more water vapour) emerging with the colourless nitrogen and carbon dioxide being exhausted from the tall exhaust chimney?**

The world has recently witnessed the power of just one aroused volcano. In the past, there have been eras when hundreds of such volcanoes erupted simultaneously.

Such eruptions destroy all life in that location. However, once a volcanic eruption stops, the products of the eruption such as lava and ash provide a new source of abundant minerals for soils and plant life in that area. In areas with warm temperatures and abundant rainfall the devastated land is soon converted to verdant life which soon attracts back plant and animal settlers. Testimony to this is to be found on the slopes of many temporarily quiet volcanoes where farmers risk life and property to reap the abundant harvests from the rich volcanic soils.

For an animated guide to volcanoes see:
<http://news.bbc.co.uk/2/hi/science/nature/7533964.stm>

** Viv Forbes has science qualifications and experience in the coal and grazing industries where he takes an interest in the influence of mineral nutrition on the health of soils, pastures and animals. He and his wife breed cattle and sheep and he is a non-executive director of a small Australian coal exploration company.*

** Mike Williamson also has science qualifications and extensive experience in coal preparation and minerals engineering. He is retired.*

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